DIAGNOSIS AND MANAGEMENT OF **CANKER DISEASES** IN ALMONDS

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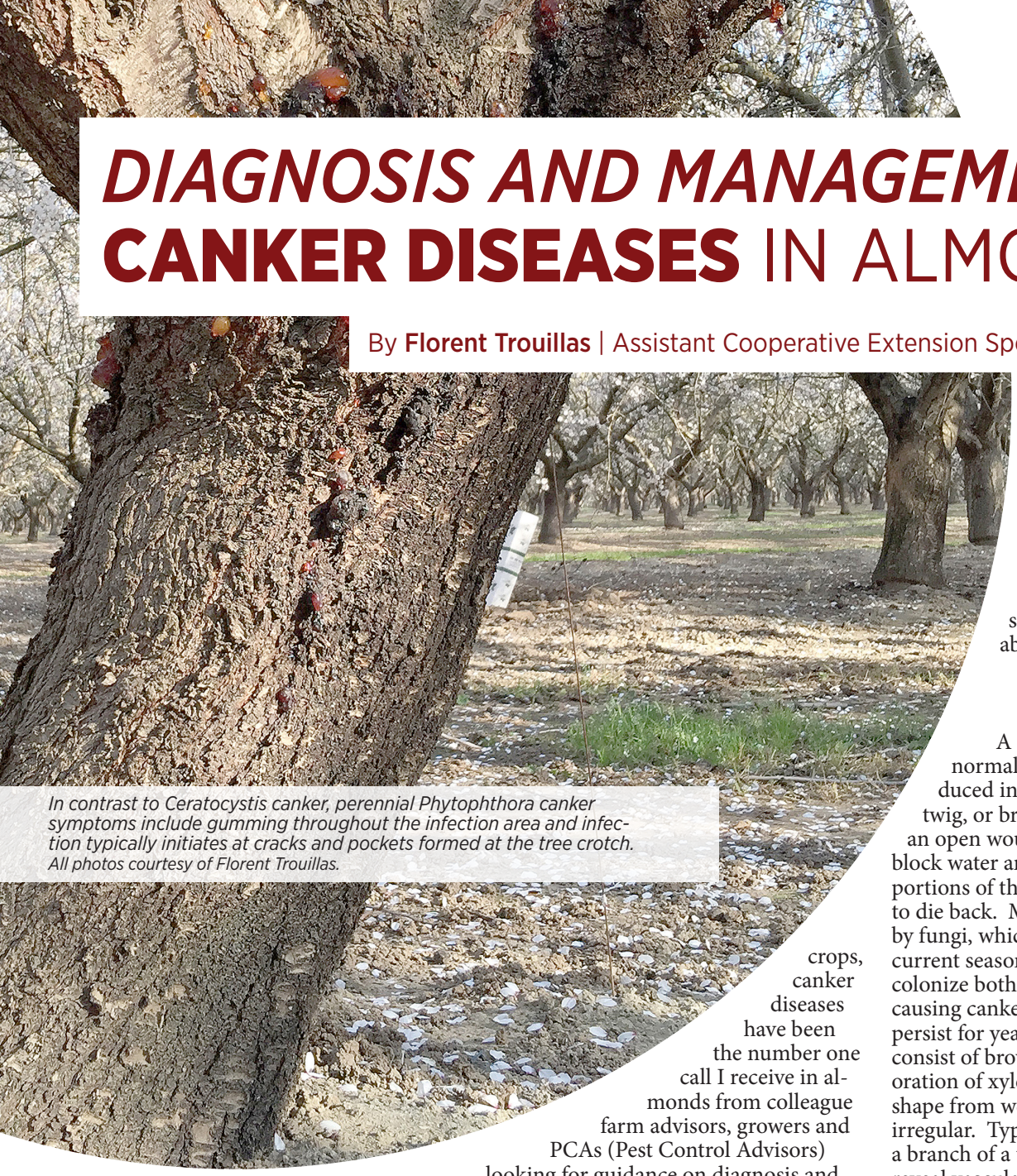

In contrast to Ceratocystis canker, perennial Phytophthora canker symptoms include gumming throughout the infection area and infection typically initiates at cracks and pockets formed at the tree crotch. All photos courtesy of Florent Trouillas.

Fungal canker diseases have long been known to affect almond trees in California, however, they have become an increasing concern to growers in recent years as they affect to a greater extent young trees, thus resulting in significant tree losses. Canker diseases can also become prevalent as orchards get older, significantly impacting yield, the lifespan of trees, production costs and profitability of almond orchards. Overall, trunk and scaffold canker diseases constitute the major cause of tree death in almond orchards in California.

As the University of California Cooperative Extension (UCCE) Specialist in Plant Pathology for the fruit and nut crops, canker diseases have been the number one call I receive in almonds from colleague farm advisors, growers and PCAs (Pest Control Advisors) looking for guidance on diagnosis and treatment. Symptoms on affected trees are very conspicuous and often alarming to growers. However, field diagnosis of almond canker diseases is difficult as symptom delineation among the various canker diseases is not clear. Hence, laboratory tests are usually required to obtain accurate disease diagnosis, which is essential to the implementation of appropriate management strategies.

With support from the Almond Board of California and with the help of farm advisors statewide, my laboratory has initiated surveys to characterize canker diseases in almond orchards and get a full understanding of the various diseases and pathogens present. In this article, I will provide an overview of the main canker diseases that impact almonds and how they can be diagnosed and prevented.

But first, let's review some general concepts about canker diseases…

What is a canker?

A canker in woody plants normally refer to a lesion produced in the bark of a plant stem, twig, or branch, often resulting in an open wound. The dead area can block water and nutrient transport to portions of the plant causing the plant to die back. Most cankers are caused by fungi, which invade bark tissue on current season wood. However, some colonize both bark and internal tissues causing canker rots or wood cankers that persist for years. Wood cankers typically consist of brown to dark brown discoloration of xylem tissues and may vary in shape from wedge-shaped to round, or irregular. Typically, if you cut through a branch of a tree, canker infections will reveal vascular discoloration, which indicates a disruption in the flow of water and nutrients through the tree's vascular system.

What are the main infection pathways and disease cycle of canker diseases? In orchard systems, cankers originate usually at wounds such as pruning wounds, mechanical injuries, sunscald and sunburn lesions, and wounds caused by insect borers. In almond, canker pathogens infect trees particularly through pruning wounds made for primary and secondary scaffold selection. Cracks in the tree crotch or on the trunk as well as shaker injury are other entry points for canker-causing pathogens in almonds. Canker diseases may go unno-

ticed during the early stages of infection and symptoms become more visible as trees get older.

Most fungal canker pathogens produce fruiting bodies on dead wood of infected host plants and appear as small, black rounded bumps embedded in the bark or wood. When present these are an important diagnostic characteristic. However, fruiting structures are not always present and many are not easily distinguished. The spores produced by these fruiting bodies serve as inoculum for new infections, mostly during wet weather. The vegetation present in the vicinity of orchards, particularly trees in riparian areas or neighboring orchards of susceptible crops may serve as inoculum sources for fungal canker pathogens affecting almonds. Once a canker disease has been established in an orchard, infected almond trees can provide additional inoculum for further infection. With Phytophthora cankers, causal pathogen infects from soilborne inoculum blown onto tree surfaces at harvest, during spraying, or during stormy weather.

How stress plays a role in the exacerbation on canker disease

Recent outbreaks of canker diseases in perennial crops have been attributed in part to drastic changes in production practices, the increase of monoculture farming, climate change and increased plant stress, the continuing adaptation of pathogens to new environments, and most importantly the global movement

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Water-soaked injury on a young tree with darker center than the surrounding healthy tissue (left). Symptoms of an established infections with amber-colored gumballs that are produced around the margin of the canker (right).

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of plant material. Trees suffering environmental stresses are more susceptible to canker diseases. Microorganisms which usually do not cause disease in non-stressed hosts may become opportunistic pathogens of stressed plants. Increases in canker diseases are common during extended periods of drought or following sudden temperature fluctuations. Drought stress can impair the plant's ability to defend against fungal invasion. Conversely, excessive watering can kill roots and predispose plants to canker pathogens.

What are the main canker diseases in California almonds and what are their symptoms?

Ceratocystis canker:

Ceratocystis canker caused by the fungal pathogen Ceratocystis fimbriata is a common disease of almond in California. While this disease is generally associated with shaker damage and bark injuries of trunks during harvest, C. fimbriata is also capable of infecting branches from fresh pruning wounds and if left untreated can kill branches, scaffolds and entire trees. Ceratocystis is spread by several species of sap-feeding beetles and fruit fly. This disease is unique to California almond production systems and thus far has not been found in other almond producing countries. Recent surveys conducted in 2015 and 2016 by our laboratory revealed that Ceratocystis canker remains one of the most prevalent canker disease of almond in California. The disease appears to be omnipresent in mechanically harvested almond orchards that repeatedly suffer bark injuries, suggesting the pathogen is ubiquitous in the Central Valley.

Infection by a Botryosphaeriaceae species with gumming at a pruning wound made for the selection of secondary scaffold (right). Band canker with oozing of amber sap that forms in a ring around the circumference of the tree (left).

Cankers are characteristic for the disease and start as water-soaked injuries that are darker than the surrounding healthy tissue. Symptoms of established infections include amber-colored gumballs that are produced around the margin of the canker, where the fungus is most active. The cankers are perennial, persist over several years, and are most active during the growing season. Ceratocystis cankers are associated with shaker injury on the trunk and pruning wounds on the scaffold. Bark injuries and pruning wounds are susceptible for up to 14 days.

Botryosphaeria cankers:

Botryosphaeria are among the most common fungi to cause canker in young trees and are often associated with growth cracks on the trunk and pruning wounds. Studies have revealed there are at least 10 different Botryosphaeria species in almond with various levels of virulence. Botryosphaeria cankers are characterized by gumming around pruning wounds made near the trunk at scaffold selection and generally appears in the third or fourth leaf.

Band canker also caused by Botryosphaeria fungi produce unique symptoms that include oozing amber sap that forms in a ring around the circumference of the tree. Young vigorous varieties or

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trees that grow quickly from aggressive nitrogen and water inputs are especially prone to band canker. Solid sprinkler irrigation or micro-sprinklers that wet the tree trunk can create conditions favorable for infection. Band canker is often an annual disease that occurs when trees are in their second to sixth leaf and usually does not necessarily reappear the following year. However, an increasing number of cases have been reported lately where cankers are being re-activated in following year. In recent years, tree death has become more common due to the fact that multiple bands can develop as the canker continues to grow in the next growing season

Eutypa dieback:

Eutypa dieback of almond occurs sporadically in the Sacramento Valley and in the northern San Joachim Valley. Eutypa dieback is caused by the fungus Eutypa lata and is a common disease of apricot, sweet cherry and grapevine. Eutypa dieback of almond is usually being found in young trees. Cankers mostly originate from pruning wounds on limbs or trunks as well as from cracks formed at the junction of scaffold branches and the trunk, extending downward the graft union or upwards into one or more scaffold branches. Amber colored gum turning dark brown to reddish brown normally exude around cracks. Irregular shaped to wedge-shaped, brown colored cankers are observed from cross sections of limbs and trunks. Limb dieback may occur several months or years after infection.

Cytospora cankers:

Cytospora has been isolated sporadically in almond orchards in California and is generally associated with pruning wounds and sunburn lesions in the canopy in orchards in their 3rd leaf or older. Symptoms of Cytospora canker include longitudinal cankers in branches and scaffolds often associated with pruning wound, vascular discoloration of the wood and moderate gumming. Cytospora species have been traditionally thought to be secondary to sunburn and other stresses or injury in stone fruits, however their prevalence in cankers suggest that this group constitutes virulent pathogens. In almond in California, several species of Cytospora have recently been detected. Overall, this group of pathogens has become of increasing concern in recent years in many fruit and nut crops.

Phytophthora cankers:

Additional pathogens causing cankers in trunks and scaffolds have included Phytophthora spp., a group of soilborne pathogens of almond. In contrast to Ceratocystis canker, perennial Phytophthora canker symptoms include gumming throughout the infection area and infection typically initiates at cracks and pockets formed at the tree crotch. Perennial Phytophthora canker develops rather quickly and can kill an entire scaffold branch or tree within one or two growing seasons. Additional aerial Phytophthora diseases include "pruning wound canker", which is recognized by its annual nature and its tendency to be initiated at large pruning wounds. Although pruning wound cankers look like perennial cankers, they are sensitive to high temperature and typically cease expansion during summer under the conditions of the Central Valley of California.

General management guidelines for canker diseases

Management of canker diseases rely for

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the most part on prevention as no chemical treatments can cure these diseases. Overall, canker diseases may be managed by avoiding bark injuries from mechanical shakers and avoid pruning trees before or during rainy weather. Management of canker diseases may rely on remedial surgery (removal of the cankered area), however, cankers are generally difficult to remove and may require multiple surgeries over several years before all of the infected tissue is removed. Removal of infected tree parts and dead trees will reduce inoculum in the orchard. When whole diseased trees are removed, the stumps should also be removed as the bark of stumps can be covered with the pathogen fruiting structures and thus serve as sources of inoculum. Adjusting sprinkler irrigation so that tree trunks and tree crotch are not wetted helps reduce the incidence of canker diseases.

Proper primary scaffold selection and avoiding stress are the most effective preventive measure to reduce risks of infection by canker pathogens. Training of young trees that creates strong branch attachment that will not split as the tree matures can help reduce infection. Scaffold branches should be selected to avoid formation of bark inclusions at the tree crotch. Pruning should be avoided during and following rainfall that permits the release of spores of the various pathogens. Pruning wound sealers and acrylic paint that act as a physical barrier may be used to protect pruning wounds and reduce infection, especially on large pruning cuts. Almond orchards occurring in the vicinity or riparian areas, old sweet cherry and apricots orchards, vineyards, walnut or pistachio orchards may be more prone to the disease.

As for Phytophthora cankers, incidence of cankers can also be minimized by proper tree planting and training. Selected branches should be spaced out vertically and laterally so as not to create pockets that retain water and favor infection by Phytophthora. The bud union of almond trees should be planted to remain above the soil line. According to USDA (United States Department of Agriculture) researcher Dr. Greg Browne at UC Davis, phosphonate sprays can be very effective for preventing and suppressing development of diseases caused by Phytophthora, but before such applications are made, growers should inquire with their pest control advisors to assess residue limitations pertaining to the treatments. Mefenoxam treatments also provide a measure of systemic protection from Phytophthora, but less is known about efficacy and economic benefits of this fungicide.

Recently, my laboratory has initiated field trials to test fungicidal compounds, biological treatments and various pastes or paints for the protection of pruning wounds and to prevent the development of canker diseases. With this work, we are hoping to identify the best products to protect pruning wounds from infection by canker pathogens.

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